

## EXPERIMENTAL AND NUMERICAL INVESTIGATION OF DIESEL ENGINE TURBOCHARGER

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### ABSTRACT

*This research work was carried out to investigate performance of turbocharger and parameters affecting performance of turbocharger. Experimental set up is developed to study the performance turbocharger at various temperature and pressure of exhaust gas of the engine. To study the effect of exit angle of turbine blade on turbocharger performance Workbench platform of Ansys CFX is used. Experimental results shows that as the engine load increases the speed of turbine shaft increases at certain level and after that it will remain constant. As per the requirement of the vehicle it is observed that we can also start the working of turbocharger when engine is running at low speed by using the proper exit angle of turbine blade.*

**KEYWORDS:** Ansys CFX, Performance, Simulation, Turbine, Turbocharger

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### INTRODUCTION

Turbochargers boost engine power by forcing more air into the cylinders. This increased air intake allows more fuel to be injected into the cylinders and results in a more powerful combustion process. Turbocharging is efficient because it recycles engine exhausts, which are normally wasted in non-turbocharged engines. As combustion gases exit the engine cylinders, they are sent to the turbocharger. The turbine is connected to a shaft that then transmits the exhaust energy to power a compressor wheel. The compressor draws in and compresses air from outside the vehicle where it passes through an intercooler, which cools the air increasing its density. This dense cold air is then sent to the cylinders to produce a more powerful combustion, resulting in greater vehicle efficiency.

### OBJECTIVE

Aim of this research is to study and investigate effect of exit angle of turbine blade on performance of turbocharger.

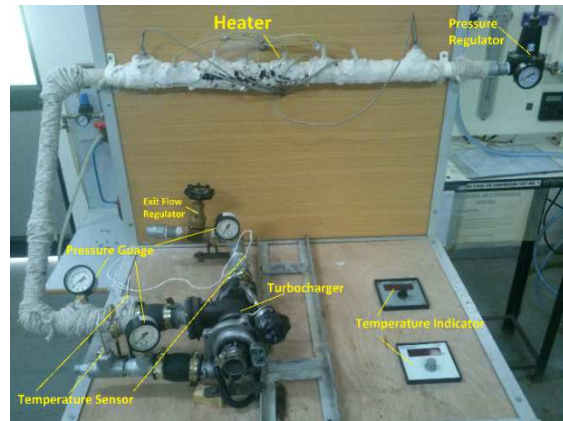
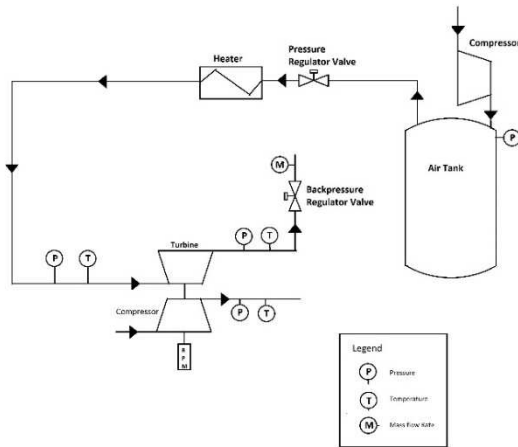
### EXPERIMENTAL SETUP

The following discussion provide information of experimental setup. A schematic Diagram can be seen in Figure 1 while Figure 2 shows image of test setup. A 2-cylinder, 2-stage air compressor is used to compress air to be used in circuit. After that an air regulator is placed for air to be regulated as per requirement. Just after that band

type heater is attached for air to be heated as per requirement. Than insulated piping was used to connect turbocharger turbine inlet to heater outlet. At near to turbine inlet and outlet, temperature sensor and pressure gauge is attached. After outlet of turbine one flow regulator valve is placed to create backpressure. Compressor outlet was also attached with pressure gauge and temperature sensor. All temperature sensors are resistance temperature detector sensors and were attached to temperature indicator. Also heater outlet was attached to temperature indicator. Hot wire anemometer was used to measure air velocity at exit of flow control valve (turbine outlet) and non-contact type tachometer was used to measure shaft Speed.

#### Following Measurements Were Taken

- Temperature and pressure on turbine inlet and outlet
- Shaft Speed
- Air speed on exit of flow regulator valve (turbine outlet).



**Figure 1: Test Rig Layout** **Figure 2: Image of Test Setup**  
(Air Compressor is Not Shown)

## EXPERIMENTAL RESULTS

Experimental was carried out to collect data on three different pressure and pressure ratio (Expansion Ratio). Here mainly back pressure is controlled (maintained) by flow control valve at exit of turbine. To get precision, repeatedly 10 result were taken at same expansion ratio. Experimental data on inlet pressure of 140kPa, 150kPa and 160kPa and with expansion ratio of 1.0769, 1.0714 and 1.0667 respectively were taken. Turbine data like pressure inlet and outlet, temperature at inlet and outlet and exit flow velocity was measured to prepare an experimental datasheet for further calculations and simulation purpose.

Mass flow rate was calculated using equation (1),

$$\dot{m} = \rho \times A \times V \quad (1)$$

Where,  $\rho$  is standard air Density, A is Area at exit of flow control valve and V is Velocity at exit of flow control valve.

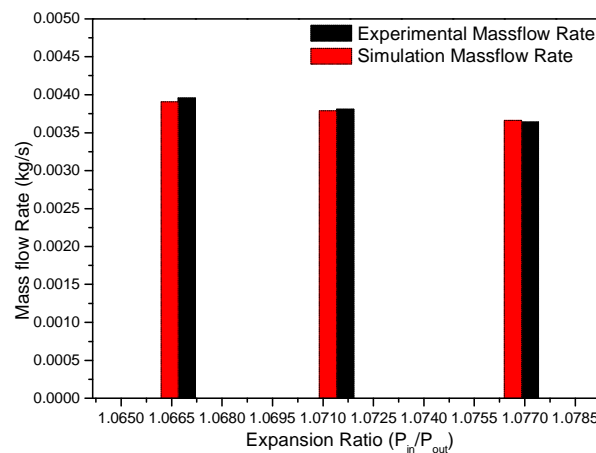
Experimental Data are shown in Table 1.

Table 1: Experimental Results

Serial No.	RPM	P in (Pa)	P out (Pa)	Expansion Ratio $P_{in}/P_{out}$	T in (K)	Air Velocity at exit km/h	MFR (kg/s)
1	12000	140000	130000	1.0769	367	84.51	0.00364263
2	12500	150000	140000	1.0714	367	88.35	0.00380814
3	13500	160000	150000	1.0667	367	91.85	0.00395900

## MODEL AND VALIDATION

Vista RTD system of Ansys workbench platform was used to create 3-D geometry of turbine impeller. Meshing was done in TurboGrid of Ansys workbench then data was shared to CFX system for further simulation. All three data point were simulated on impeller geometry and results of mass flow rate of all three data point were compared with experimental mass flow rate. Results are represented in graph. 1.



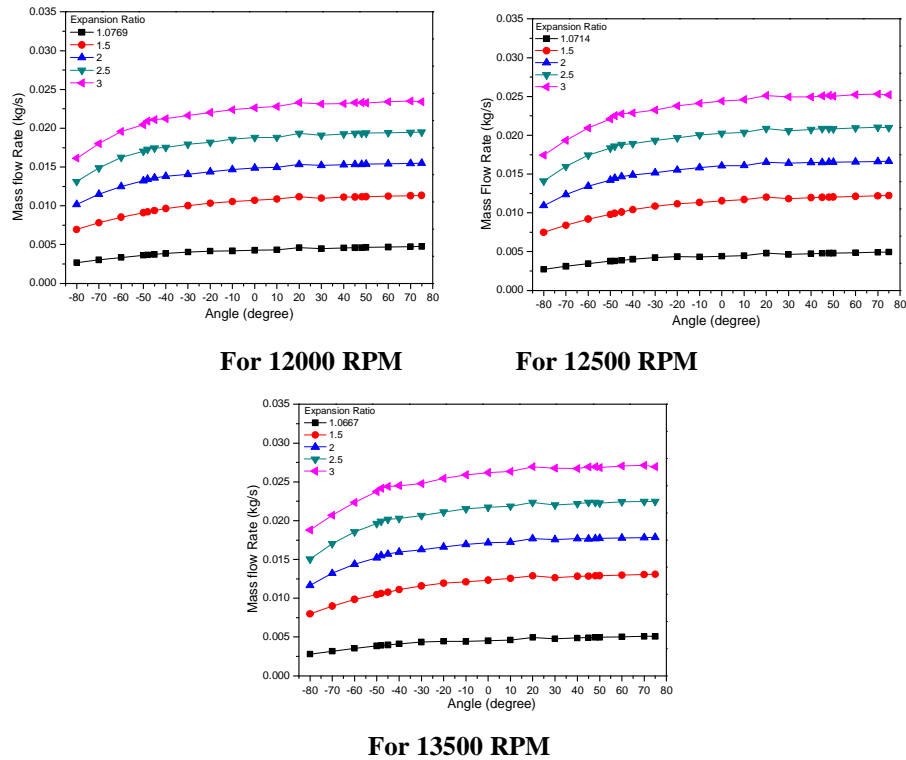
**Graph 1: Comparison of Experimental Mass Flow Rate to Simulation Mass Flow Rate**

Here from graph. 1 it is concluded that experimental results and simulation results are approximately same. This process validate impeller geometry created in Ansys.

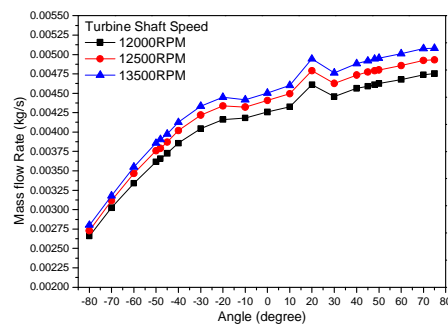
## PARAMETRIC STUDY

Based on validated impeller geometry parametric study was carried out to investigate the effects of impeller blade exit angle on performance of turbocharger. Different angles of impeller geometry were changed and simulated in Ansys CFX for all three data points and graphs were prepared for all three data points up to certain pressure ratio for each. Graphs for parametric results are shown in graph.2.

Graph 3 shows mass flow rate on different impeller exit angle for different speed increase with increase in impeller exit angle.



**Graph 2: Parametric Study on Different speed and Different Initial Expansion Ratio**



**Graph 3: Behaviour of Mass Flow Rate on Different Impeller Exit Angle for Different Speed**

## CONCLUSIONS

This research work carried to investigate the performance of turbocharger under different loading condition of engine experimentally. Parametric study is done in Ansys CFX. The following conclusion is drawn from this study: At inlet of turbine of turbocharger pressure condition of air (exhaust gas in actual engine) 1.4bar, 1.5bar and 1.6bar at 367K the turbine shaft speed observed are 12000, 12500, and 13500 respectively. As the expansion pressure ratio or mass flow rate of exhaust gas increases speed of the turbine shaft increases that will increase the mass flow rate from compressor to engine. After pressure ratio of 3.7, 3.8 and 3.9 of initial expansion ratio of 1.769, 1.0714 and 1.667 respectively, the speed of turbine shaft and flow rate becomes constant. It is observed that as the exit angle of turbine blade decreases the turbocharger can also start working at low mass flow rate from the engine.

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